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New Design of Hingeless Helicopter Rotor Improves Stability

The blades of conventional articulated rotor helicopters are attached to the rotor hub with hinges to permit flapping and lead-lag motion of the blades perpendicular and parallel to the plane of rotation. In hingeless rotor helicopters, cantilever blades are attached directly to the rotor hub, thereby substantially reducing the cost and complexity and increasing the reliability of the helicopter rotor. However, some form of aerolastic instability may be exhibited partly because the damping of lead-lag bending motion of the cantilever blades is very small. For many hingeless rotors, the minimum lead-lag damping occurs when the rotor is operating at low thrust and the aerodynamic forces acting on the blades are small; accordingly, during ground contact, ground resonance instability may be encountered if the structural damping of the rotor blades is not sufficiently high or if auxiliary lead-lag dampers are not installed. Attempts to prevent hingeless rotor instabilities by design modifications have not always been successful; auxiliary lead-lag dampers may be installed, but increases in weight, cost, and complexity compromise the inherent advantage of the hingeless rotor.

Increased damping of the blade lead-lag motion at zero thrust is provided aerodynamically by a new design that combines structural coupling of flap bending and lead-lag bending with the coupling between pitching and lead-lag bending of the blade. The structural flap-lag coupling is provided by orienting the principal flexural axes of the blade cross section at an angle of up to 30° to 45° with respect to the plane of rotation rather than roughly 0° to 5° of conventional helicopter rotor blades. Coupling of the blade pitch angle with lead-lag bending of the blade can be realized kinematically by proper arrangement of the geometry of the blade pitch controls. Pitch-lag coupling can also be realized structurally by special design of the blade material elastic properties or by blade cross-section geometries that displace the blade center of mass vertically with respect to the shear center.

Because of hysteresis in the blade material, typical hingeless rotor blades exhibit roughly one-half to one-percent structural damping, but about four to five percent damping (depending on the lead-lag natural frequency of the rotor blade) is required to prevent ground resonance instability. The combination of structural flap-lag coupling and pitch-lag coupling described above provides damping of six to ten percent, depending on the magnitude of the coupling parameters.

Note:

Requests for further information may be directed to:

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Patent status:

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to:

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